



CCRN Workshop on Extreme Weather and Hydrology – “Lessons Learned from the Western Canadian Floods of 2013 and Others”

**Grande Rockies Resort, Canmore, AB
11 – 12 February, 2014**

The purpose of this Workshop is to evaluate, analyse and synthesise a case study of extreme weather and hydrology with a focus on the Western Canada Floods of 2013. The Workshop will first compile a hydrometeorological diagnosis of the June 2013 floods in Western Canada and then relate this to broader atmospheric and hydrological dynamics and change and to extreme hydrometeorological events in North America. It will synthesise descriptions of hydrometeorological processes and statistical properties, hydrological and atmospheric modelling and water management implications as they relate to the Western Canadian Flood of 2013 and related events.

Workshop Agenda

| Tuesday, 11 February | | |
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| 8:00 – 8:30 | | Welcome and Introduction |
| 8:00 – 8:10 | John Borrowman, <i>Mayor of Canmore</i> | Welcome to Canmore and Opening Remarks |
| 8:10 – 8:20 | Howard Wheeler, <i>Univ Saskatchewan</i> | Introductory Remarks on CCRN |
| 8:20 – 8:30 | John Pomeroy, <i>Univ Saskatchewan</i> | Introductory Remarks on the Extreme Events of 2013 and the Objectives for the Workshop |
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| 8:30 – 10:00 | Chair: Sean Carey | Session 1: Observations and Diagnosis of the 2013 Extreme Events in Western Canada |
| 8:30 – 9:00 | Ron Stewart, <i>Univ. Manitoba</i> | Atmospheric Overview of the June 2013 Flooding Event |
| 9:00 – 9:30 | John Pomeroy, <i>Univ. Saskatchewan</i> | Overview of the Hydrometeorology of the Canadian Rockies Flood of June 2013 |
| 9:30 – 10:00 | Colleen Walford, <i>Alberta Environment & Sustainable Res. Dev.</i> | Flood Forecasting Methodology in Alberta |
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| 10:00 – 10:30 | | Coffee Break |

Workshop Agenda

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| 10:30 – 12:00 | Chair: Ron Stewart | Session 1: Observations and Diagnosis of the 2013 Extreme Events in Western Canada (Continued) |
| 10:30 – 11:00 | Bill Duncan, <i>Water Security Agency of Saskatchewan</i> | June 2013 Rainstorm Runoff Event in Saskatchewan River Basin: Saskatchewan Perspective |
| 11:00 – 11:30 | Sean Carey, <i>McMaster Univ.</i> | The Flood in the Elk River Valley, BC |
| 11:30 – 12:00 | Masaki Hayashi, <i>Univ. Calgary</i> | Potential Roles of Groundwater in Mitigating or Exacerbating the Impacts of Floods |
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| 12:00 – 1:00 | | Lunch Break |
| 12:30 – 1:00 | Don Cline, <i>Office of Hydrology, NWS, NOAA</i> | Luncheon Speaker: Extreme Hydrology Prediction in the United States |
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| 1:00 – 2:00 | Chair: John Pomeroy | Session 1: Observations and Diagnosis of the 2013 Extreme Events in Western Canada (Continued) |
| 1:00 – 1:30 | Julie Thériault, <i>UQAM</i> | The June 2013 Alberta Flooding Event: Climatology, Synoptic Conditions and Precipitation Fields |
| 1:30 – 2:00 | Yvonne Martin, <i>Univ. Calgary</i> | Debris Flow Activity in Kananaskis Country, Alberta: The Link for Sediment Transfer Between Hillslopes and Rivers |
| | | |
| 2:00 – 3:30 | Chair: Al Pietroniro | Session 2: Modelling the Flood |
| 2:00 – 2:30 | Logan Fang, <i>Univ. Saskatchewan</i> | CRHM Modelling of Mountain Hydrological Processes in Marmot Creek during the Flood |
| 2:30 – 3:00 | Bruce Davison, <i>Environment Canada</i> | Prediction and Reanalysis of the Flood and High Precipitation Event |
| 3:00 – 3:30 | Yangping Li, <i>Univ. Saskatchewan</i> | WRF Model Simulation of the June 2013 Alberta Flooding Event |
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| 3:30 – 4:00 | | Coffee Break |
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| 4:00 – 5:30 | Presenter and Chair: Don Cline, Office of Hydrology, NWS, NOAA | Session 3: Snow Data Assimilation (SNODAS) |
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| 5:30 – 6:30 | | Reception (Lake Louise Room) |
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| 6:30 – 8:30 | Howard Wheeler Presiding | Dinner (Banff and Lake Louise Rooms) |
| 7:25 – 7:30 | John Borrowman, <i>Mayor of Canmore</i> | Welcoming Remarks |
| 7:30 – 8:00 | Andy Esarte, <i>Town of Canmore</i> | Canmore and the Flood – Anticipation, Response, Impact on a Municipal Level |

Workshop Agenda

| Wednesday, 12 February | | |
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| 8:30 – 10:00 | Chair: Howard Wheeler | Session 4: Learning from the Flood |
| 8:30 – 9:00 | Danny Marks, <i>USDA, ARS</i> | The Sensitivity of Mountain Snowcovers to Temperature, Humidity, and Phase Change in a Warming Climate |
| 9:00 – 9:30 | Paul Whitfield, <i>Unv. Saskatchewan</i> | Changes to Autumnal Streamflow Features in the Rocky Mountains of North America |
| 9:30 – 10:00 | Al Pietroniro, <i>Environment Canada</i> | Measuring the Flood from BC to Manitoba – Challenges and Opportunities |
| 10:00 – 10:30 | | Coffee Break |
| 10:30 – 12:00 | Chair: Danny Marks | Session 5: Related Events and Scientific Insights on the Processes Involved |
| 10:30 – 11:00 | Katrina Bennett, <i>Univ. Alaska</i> | Extreme Streamflow in Interior Alaska River Basins |
| 11:00 – 11:30 | Ric Janowicz, <i>Yukon Dept of Environment</i> | 2013 Extensive Yukon Ice Jam and Freshet Flooding |
| 11:30 – 12:00 | Roy Rasmussen, <i>National Center for Atmospheric Research</i> | High Resolution Simulation of an Extreme Snow and Rain Event in Colorado in both a Current and Future Climate |
| 12:00 – 1:00 | | Lunch Break |
| 1:00 – 3:00 | | Session 6: Breakout Groups |
| 1:00 – 3:00 | Rapporteur: Sean Carey Facilitator: Paul Whitfield | Group 1 - Describing the Flood and its Statistical Properties in a Changing Climate (Canmore Room) |
| 1:00 – 3:00 | Rapporteur: Bruce Davison Facilitator: Graham Strickert | Group 2 - Modelling the Flood – Challenges and Opportunities (Lake Louise Room) |
| 1:00 – 3:00 | Rapporteur: Amin Elshorbagy Facilitator: Bob Sandford | Group 3 - Water Management Implications and Mitigation of the Flood (Banff Room) |
| 3:00 – 3:30 | | Coffee Break |
| 3:30 – 5:00 | | Rapporteur Reports from Breakout Groups |
| 3:30 – 3:50 | Sean Carey | Report from Group 1 |
| 3:50 – 4:10 | Bruce Davison | Report from Group 2 |
| 4:10 – 4:30 | Amin Elshorbagy | Report from Group 3 |
| 4:30 – 5:00 | Bob Sandford, John Pomeroy, Howard Wheeler | Summary and Synthesis of Breakout Group Reports |
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Workshop Agenda

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| 5:00 – 7:30 | | Dinner (Workshop Participants on their own for Dinner in Canmore) |
| 7:30 – 10:00 | Chair: Graham Strickert | Evening Public Event and Panel Discussion on the Flood (Canmore Collegiate High School) |
| 7:30 – 7:35 | John Borrowman, <i>Mayor of Canmore</i> | Welcoming Remarks |
| 7:35 – 8:05 | Roy Rasmussen, <i>National Center for Atmospheric Research</i> | The Colorado Great Front Range Flood of 2013 – Lessons for Alberta |
| 8:05 – 10:00 | Roy Rasmussen, John Pomeroy, Howard Wheeler, Ron Stewart, Al Pietroniro, Kevin Shook | Expert Panel and Open Discussion |

Abstracts

Atmospheric Overview of the June 2013 Flooding Event

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This presentation provides an overview of some of the atmospheric features associated with the June 2013 flooding event. Information was obtained from a variety of sources including satellites, operational model analyses, lightning network, radar, and weather stations. Substantial snowfall occurred over the mountains in the preceding winter and above-normal precipitation also occurred in the month before the event. The event itself was linked with a mid-level closed low to the west of the region and a surface low pressure centre initially to its south. This configuration brought warm, moist unstable air into the region that led to dramatic, organized convection with an enormous amount of lightning and some hail. Both the convective and stratiform components were affected by the topography. Initially, precipitation rates were very high but decreased to lower values as the precipitation shifted to long-lived stratiform conditions. Similar events, such as June 2002, have occurred over this region although this 2002 event was much colder and had little if any convection over south-western Alberta.

Abstracts

Overview of the Hydrometeorology of the Canadian Rockies Flood of June 2013

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The heavy rainfall associated with the Alberta floods of late June 2013 was centred on the Front Ranges of the Canadian Rockies including Marmot Creek in the Kananaskis Valley. Marmot Creek Research Basin was the subject of intensive hydrometeorological observations as part of the Changing Cold Regions Network study when the storm occurred. These observations provide a specialized insight into mountain hydrometeorology and hydrological processes associated with the generation of a flood from the extreme weather event. Alpine and treeline snowpacks still held of hundreds of mm of water equivalent and some soils had reduced water storage potential due to ground frost and or soil moisture storage. Rainfall intensities were high but not exceptional – what was exceptional was the volume and steady rate of rainfall, the large area covered by heavy rainfall and the lack of substantial variation in rainfall volume with altitude. Initial rain was relatively warm and formed runoff or sub-surface flow quickly. Runoff contributing areas increased rapidly after the initiation of rainfall. Snowmelt contributions due to rapid melting associated with water vapour deposition during the rainfall were substantial at high elevations. A transition from rainfall to snowfall near the end of the high precipitation event increased snow accumulation in the mountains rather than contributed to further runoff generation. It is difficult to analyse streamflow records for this event because many mountain stream gauges in the region were destroyed during the flood, including those in Marmot Creek, by high, fast water carrying debris. However, an examination of the Bow River records shows that large floods of this magnitude were experienced in the late 1800s and early 1900s and that the magnitude of peak flows arriving at Calgary appeared to be declining until the recent flood. This decline is consistent with the long term decline in flows from Marmot Creek. Floods of magnitudes similar to 2013 are associated with a large spatial extent to runoff generation involving both the Upper Bow River Basin and the Front Ranges of the Canadian Rockies

Abstracts

Flood Forecasting Methodology in Alberta

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This presentation is intended to provide a brief overview of the event operations methodology followed by Alberta's River Forecast Team during flood events while putting it in the context of the June 2013 event. Points of discussions will include: group mandate and function, data quality assurance, data network, forecast models, weather data, communications and current projects.

The River Forecast Team, made up of five forecasters and 4 technologists, has four main functions which are as follows: real-time flow forecasting and support to partners, near real-time data quality management, daily natural flow forecasting and water supply forecasting. Approximately 400 hydrometric and 330 meteorological stations are quality controlled on a daily basis. The Forecast Team has 146 forecast points in the province, 63 of which were located in the upper portions and along the mainstem rivers in the five river basins affected by the weather event in June of 2013. Of the 180 external groups in the River Forecast Team notification system, 80 were communicated with in the first few days of the event with up to 400 calls being managed by the River Forecast Team in the first 48 hours of the event.

Abstracts

June 2013 Rainstorm Runoff Event in Saskatchewan River Basin: Saskatchewan Perspective

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The rainfall event of June 19-22, 2013 in the eastern slopes of the Alberta Rockies and foothills generated significant flows on both the North and South Saskatchewan Rivers in Saskatchewan. On the South Saskatchewan River upstream of Lake Diefenbaker, the peak flow was in excess of 1:100 and resulted in extensive flooding of the river valley with impacts to pump stations, ferries, and agricultural lands. Lake Diefenbaker is a large multi-purpose reservoir on the South Saskatchewan River created by the completion of the Gardiner and Qu'Appelle River dams in 1967. Operation of Gardiner Dam during this event significantly reduced the peak flow downstream along the South Saskatchewan River and in the Saskatchewan River. Nevertheless, the peak outflow was the highest since the completion of the dams, and resulted in impacts to agricultural lands in the valley and to ferry operations.

On the North Saskatchewan River, the metered peak flow is estimated to have a return period of 1:10. However until the metering was done and the shift correction made, forecasted flows based on the upstream gauge (NSR at Deer Creek) were much higher, causing concern at critical locations downstream including North Battleford and Prince Albert.

On the Saskatchewan River, the combined flows largely usurped the ability of the two SaskPower reservoirs to attenuate the flow peaks. Forecasted peak outflows from SaskPower's most downstream dam, E.B. Campbell Dam, were expected to overtop the sole access road to Cumberland House. As a result the Northern Village of Cumberland House and the adjacent community of Cumberland House Cree Nation were evacuated.

Abstracts

The Flood in the Elk River Valley, BC

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The Alberta floods in June 2013 garnered considerable attention due to the extensive nature of destruction and the loss of life. The same 19-21 June event that deposited up to several hundred millimeters of precipitation on the east slope of the Rockies also tracked through the East Kootenay region of southern British Columbia, and states of emergency were declared for all communities of the upper Elk Valley including Elkford, Sparwood, Hosmer and Fernie. Physiographically, the Elk Valley bears considerable similarity to the eastern slopes of Alberta, with steep montane environments that straddle several ecozones and a similar geology and soils. The trans-boundary Elk River is the major drainage of the valley, which contains several large tributaries including the Fording River. Recent attention has been given to increased levels of Selenium and other constituents in the Elk River and tributaries associated with five surface coal mines that operate in the valley. While climate and hydrometric instrumentation and historical records are relatively sparse for this region (there are five operating Water Survey of Canada stations and one Environment Canada climate station at Sparwood), several instrumented watersheds established in 2012 supplement the network to provide a more extensive spatial picture of the 2013 flood event.

At the onset of precipitation, major rivers and headwater catchments were on the descending limb of snowmelt freshet hydrograph, and most snow below 2200 m had melted. Precipitation in the week before was limited, yet soils were relatively wet from a protracted melt period. Rainfall began late evening on 19 June when maximum intensities were recorded equivalent to a 5-year return period (~10 mm/hr). Intensities were greater than 4 mm/hr for over 12 hours, and then gradually declined without much interruption until the evening of the 21 June. A network of 5 total precipitation stations within the valley each recorded between 100 and 110 mm of precipitation during the event. There were no notable changes in precipitation with elevation between 1400 to 2100 m. In terms of return period for 24 hour precipitation, IDF curves for Sparwood suggest that the storm return period was in excess of several hundred years if not longer. Soon after precipitation began, headwater catchments responded rapidly and major rivers began to rise. Of the four headwater catchments monitored in the upper Elk Valley, three stations were destroyed and the fourth channel adjustment limited data quality. Of the Water Survey gauges, preliminary flows indicate two stations (Fording River at Mouth 08NK018 and Elk River at Fernie 08NK002) reached historical instantaneous and daily flows on 21 June, whereas other WSC stations had maximum flows in the upper quintile of historical high flows. Length of data for most stations is approximately 40 years, limiting the robustness of statistical techniques to gauge return periods, yet both Fording River at Mouth and Elk River at Fernie had preliminary flows ~25% higher than the previous recorded daily maximum flows. It is important to highlight that flood protection measures put in place for the City of Fernie following a flood in 1995 were largely effective, with limited flood damage reported.

Abstracts

Potential Roles of Groundwater in Mitigating or Exacerbating the Impacts of Floods

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Groundwater is usually hidden from our eyes, but essentially all surface water bodies (i.e. rivers and lakes) are connected to groundwater. Except for the runoff from urban regions, the majority of water flowing through rivers has once been groundwater and will become groundwater again through the interaction between river and the underlying fluvial aquifers. The soils, talus deposits, glacial deposits, and fractured bedrock in the mountains can store a large amount of rain, snowmelt, and glacier melt water; and potentially provide a buffering mechanism against the quick release of water input. The bank storage along river channels during the passing of flood peak can also provide a buffering mechanism. However, the build up of pore pressure during heavy storms can trigger slope failures and subsequent debris flow. The rising water table in fluvial aquifers can flood the basement of buildings built on the flood plain. I will briefly discuss these positive and negative roles of groundwater with respect to flood impacts using examples from our hydrological studies in mountainous watersheds.

Abstracts

Extreme Hydrology Prediction in the United States

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The National Weather Service (NWS) has been tasked to provide flood warnings for the United States since 1890. In early years forecasting was limited to travel time and crest relationships for major navigable rivers. Advancements in hydrologic science were incorporated over time, such as the introduction of unit hydrograph concepts in the 1930s. The first NWS River Forecast Center (RFC) was established in 1946, and twelve more were established over the next 33 years to provide complete national coverage. Rapid improvements in science and technology during the 1970s led to the development of an enterprise modeling and forecast system called the NWS River Forecast System (NWSRFS), with corresponding improvements in the quantity, frequency and lead time of forecasts. In 2011 the NWS launched the Community Hydrologic Prediction System (CHPS), which incorporated the models and tools of NWSRFS into a new service-oriented architecture built on the Deltares Flood Early Warning System (FEWS). The new architecture enables more rapid incorporation of new models, as well as new opportunities for managing the forecast process.

The NWS Hydrology Program is now preparing for a new era of expanded forecasting to provide a broader array of water resources information to support decision-making. While its history has been focused on high flows and floods, the NWS is preparing to provide new information on low flows, droughts, water availability and quantity, and other water resources information needed to address grand challenges of water security, water quality and hydrologic extremes. Through an innovative Federal partnership called Integrated Water Resources Science and Services (IWRSS), the NWS, U.S. Geological Survey, and the U.S. Army Corps of Engineers are developing ways to improve system interoperability and data synchronization, develop a joint framework for flood inundation mapping, and expand modeling capabilities. The agencies are considering a new concept of a National Water Modeling Framework that would allow each agency to leverage national investments made towards an Earth System approach to water modeling, working in concert with legacy agency systems designed for water science, prediction and management. The new NOAA National Water Center, opening in 2014, will provide a state-of-the-art facility to serve as a catalyst for research and operations to support the new era of water resources forecasting.

Abstracts

The June 2013 Alberta Flooding Event: Climatology, Synoptic Conditions and Precipitation Fields

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The goal of this study is to investigate the atmospheric conditions associated with the major flooding event that occurred over Alberta, Canada in June 2013. More than 200 mm of rain were recorded in Alberta, with a peak between 0000 UTC and 0600 UTC 20 June 2013. To gain insight into the frequency occurrence of heavy precipitation events, a climatology study of precipitation in the Banff-Calgary area was conducted. This preliminary analysis suggests that a maximum amount of precipitation was recorded in June 2005 in Calgary from 1961-2011. A larger-scale overview of the event was then analyzed. A cutoff low located aloft created favourable condition for the formation of the low-pressure system. The cyclonic circulation of the surface low-pressure system produced sustained upslope wind, which was associated with precipitation on the lee side of the mountain. A preliminary analysis of the GEM-LAM 2.5 km forecasts was conducted using vertical cross-sections along the mountainside. It shows that the low-pressure system transported warmer air in southeastern Alberta that lowered the 0°C isotherm. Heaviest precipitation started at around 0000 UTC, where snow and cloud droplets were produced aloft from upslope wind. At 0600 UTC, the upslope flow produced cloud droplets, snow and graupel over the mountain range. All solid precipitation types melted completely into rain before reaching the surface. The GEM-LAM 2.5 km outputs were also compared with radar reflectivity. Further investigation is needed to clarify the critical mesoscale and microphysics processes leading to such an extreme event. For instance, semi-idealized simulations will be conducted to study the relative importance of soil moisture, snowpack, terrain and precipitation intensity on the severity of such event.

Abstracts

Debris Flow Activity in Kananaskis Country, Alberta: The Link for Sediment Transfer Between Hillslopes and Rivers

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Debris flows are a relatively common geomorphic occurrence in the Kananaskis watershed. In the past three decades, two major occurrences of multiple debris flows have occurred; one in 1995 and the other in 2013. Both of these periods of intense debris flow activity were associated with heavy and continuous precipitation for several days leading up to the events. In both cases, the debris flow events occurred towards the end of the precipitation event.

Debris flow activity is an important geomorphic process in mountainous regions. Debris flows provide the connection between material eroded on hillslopes and that eventually becomes part of the fluvial system. Over time, material from hillslope erosion collects in steep, low-order channels (these channels may not have permanent water flow) due topographic convergence in these locations. The recharge of material into these low-order channels is a requirement for the initiation of debris flows. Large-magnitude, low-frequency precipitation events may then destabilize this material, resulting in a debris flow. During the debris flow event, material is transferred and deposited in channel zones of lower gradient. Once the material is deposited in a channel reach dominated by fluvial processes, this material will in due course be transferred along the channel system.

Initial investigations have noted a difference between debris flow characteristics on the east and west facing slopes of the main valley. On east facing slopes, there are fewer debris flows and they often seem to initiate from zero-order streams and travel relatively short distances before depositing in first or second order streams. East-facing slopes in Kananaskis consist of subdued escarpments associated with anacinal slopes. The regolith is relatively deep with glacially and paraglacially derived sediments. Tree cover on these slopes is relatively dense. In some locations, these same channels also serve as snow avalanche paths during winter months. While debris flows occur mostly in June or July during notable precipitation events, snow avalanches generally occur January to March. In contrast to the east-facing slopes, the vegetation is generally sparse on west-facing slopes. The west facing slopes in some locations show more complex fault arrangements than the east facing slopes. The slopes are underdip to dip cataclinal slopes and regolith coverage is generally of limited depth. Glacial deposits are generally found at the bottom of hillslopes. Debris flows initiate and mobilize material from the streambeds of first to third order streams. Streams that run parallel to the mountain ranges or that cut through them into the next range appear to have more debris flow activity. On both the east facing and west facing slopes, the new debris flows have exposed evidence of past debris flow activity.

Abstracts

CRHM Modelling of Mountain Hydrological Processes in Marmot Creek during the Flood

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A physically based hydrological model was developed using the Cold Regions Hydrological Modelling platform (CRHM) for the Marmot Creek Research Basin (~9.4 km²). The model includes major cold and warm season hydrological processes including snow redistribution, sublimation, melt, runoff over frozen and unfrozen soils, evapotranspiration, sub-surface runoff on hillslopes, groundwater recharge and discharge and streamflow routing. Uncalibrated simulations were conducted for eight hydrological years covering 2005-2013. The model performed relatively well for simulating snow regime. Model simulations of streamflow generally matched with the observations at the basin scale, with a NRMSD of 70%, small model bias (-1%) and a Nash-Sutcliffe efficiency (NSE) of 0.47. At the sub-basin scale, values of NRMSD were larger, from 71 to 86%, and NSEs were lower, from 0.1 to 0.32, though underestimation of streamflow was within 10%. For 2013, no direct comparison between simulated and observed streamflow was possible as gauging stations were destroyed in the June 2013 flood. However, records of stage in the basin suggest that modelled peak streamflow lagged actual flows during June flood. This suggests that current model structure and parameterisation has previously undetected inadequacies in simulating peak streamflow timing during extremely wet conditions. The model was used to diagnose responses of hydrological processes in June flood for different environments such as alpine, treeline, montane forest and forest clearings in Marmot Creek in order to better understand flow pathways and model deficiencies in extremely wet conditions. To examine the model sensitivity to antecedent conditions, “virtual” flood simulations were conducted using a week (17 to 24 June 2013) of flood meteorology imposed in the meteorology of the same period in other years (2005 to 2012) as well as in different months (May to July) of 2013. The results show sensitivity to snowpack, soil moisture and forest cover with the highest runoff response to rainfall from locations in the basin where there are recently melted or actively melting snowpacks.

Abstracts

Prediction and Reanalysis of the Flood and High Precipitation Event

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The Canadian Precipitation Analysis (CaPA) and Environment Canada's Global Environmental Multi-scale (GEM) Numerical Weather Prediction (NWP) model temperature field were used to drive the hydrological model WATFLOOD and hydrologic land-surface-scheme MESH from January 2002 to December 2013 for a number of headwater basins of the South Saskatchewan River basin. Calibration was performed for 2002 to 2009 and validation from 2010 to 2013, with particular emphasis on the 2013 flood flows on the Bow River at Banff and Calgary. Indications of an underestimation of precipitation within CaPA will be discussed, along with the results of the model simulations.

Abstracts

WRF Model Simulation of the June 2013 Alberta Flooding Event

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The Weather Research and Forecasting (WRF) Model was used to simulate 2013 Alberta flooding event. In the simulation, there were 2 nested domains; the resolutions for the inner/outer domain were 3 km/27 km respectively. The boundary condition was forced by NCEP reanalysis with 1 degree resolution every 6 hours. WRF simulated precipitation was then compared to CaPA and CMOPH data for calibration. The simulated timing and location of the precipitation, and the generated precipitation rates closely fit the observation data, indicating that WRF model is capable to reproduce this type of severe event. Water vapor budget analysis were applied to find out the moisture sources that caused the flood to occur, including the large scale moisture convergence by advection, orographic blocking and lifting, local recycling of the water through evaporation, etc. Sensitivity test of local topography was done with reduced-mountain height, less roughness, to see how much precipitation was contributed by the blocking effect, and how the correct timing and location of the precipitation relies on the micro-meteorology process within the Rocky mountain. This work is a preparation for future WRF simulations under global warming scenario to see whether this type of extreme events may happen more frequently in future.

Abstracts

Canmore and the Flood – Anticipation, Response, Impact on a Municipal Level

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The June 2013 hydro-climatic event that affected large portions of the southern Canadian Rockies led to the most expensive natural hazard in recent times in Canmore. The weather forecast called for 150 mm of rain on June 19 and 20. By June 21, up to 265 mm of rain had fallen in the region with intensities up to 17 mm/hr. Hundreds of debris flows and debris floods occurred in the region. The Town of Canmore and their contractors and consultants reacted to the best of their capabilities to the challenging and ever changing situation helping to maintain access roads and potentially avert an even bigger disaster. While this event was disastrous from an economic point of view and put lives at risk, it provides a unique opportunity to improve on disaster response, reduce vulnerability, improve resiliency, and embark on a systematic approach to quantify hazards and risks on the alluvial fans in the area. This will lead to systematic fan hazard and risk maps that will guide future developments and be translated into engineering measures to reduce risk to tolerable levels. Risk tolerance will be determined by the Town and impacted parties through significant public and stakeholder consultation. Once this risk evaluation process is complete, mitigation works can be optimized to reduce risk to tolerable levels while achieving a balance between mitigation costs and their respective benefits in terms of loss of life and economic losses. In addition, and as part of the risk-management process, improved river forecasting systems and debris-flow warning systems are being proposed in collaboration between academia, government, the consulting industry and the Town. For that purpose, the Town has engaged some of the most experienced consultants on this subject in Canada, is collaborating with three experts from academia in the form of a high-level independent review board, and has engaged Austrian debris flow and debris flood experts to work with the Town. The ongoing and future work is designed to make Canmore a safer place from geohazards.

Abstracts

The Sensitivity of Mountain Snowcovers to Temperature, Humidity, and Phase Change in a Warming Climate

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Devastating floods in mountain regions of the western US and Canada can result from rapid snowmelt during mid-winter rain-on-snow (ROS) events. Key components of snowmelt flooding during ROS are conditions prior to the storm, the combination of temperature, humidity and wind during the event, and the extent to which the snowcover is exposed to the wind. The critical antecedent condition is extension of the snowcover to lower elevations spanning the rain/snow transition zone. In the mountain basins this significantly increases the snow-covered area (SCA) and the volume of water stored in the snowcover. During ROS events the elevation of the rain/snow transition can rise, resulting in rain to occur over large areas. During typical conditions the mountain snowcover is generally cooled by evaporation (latent heat flux) and warmed by sensible heat flux, such that turbulent fluxes have little effect on the energy state of the snowcover. However, during ROS condensation occurs on the snow increasing melt energy by 50 – 100 times such that most of the energy for snowmelt comes from the combination of sensible and latent heat exchange. If the SCA is extensive and exposed to the wind, the surface water input (SWI) may be more than doubled by the addition of snowmelt to the rain. Data indicate that as the climate warms, higher temperatures and more humid conditions during storms may result in more frequent flooding events from mountain regions.

Abstracts

Changes to Autumnal Streamflow Features in the Rocky Mountains of North America

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In a warming/warmed climate in mountainous regions we would expect to see a transition from early winter snowfall to rainfall events. These rainfall events can result in the generation of runoff by direct overland flow or rain-on-snow runoff or increase the soil moisture status depending on antecedent conditions. This stands in contrast to the situation in colder conditions where early winter precipitation tends to occur as snowfall and contributes only to the accumulation of the seasonal snowpack. In many published studies, changes in the autumnal climate and hydrology are obvious, but non-significant, because the variability in timing and magnitude of runoff events. In this study an alternative approach is presented. Shifts in frequency and duration of autumn rainfall and snowfall are detected from 116 climate stations in the Rocky Mountains. Similarly, floods occurring in September through December are detected from 128 hydrometric stations in the Rocky Mountains using a baseflow filter. Trends in these events with respect to flood magnitude, frequency, and duration are then assessed. While significant changes in all flood attributes are detected at only about 10% of the sites, this is much greater than expected by chance alone. The spatial distribution of these events and changes in their nature show important changes in autumnal hydrology as rainfall and rain-on-snow events increase and suggest that the progression of a shift towards an increasing number of autumnal floods is being observed.

Abstracts

Extreme Streamflow in Interior Alaska River Basins

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Climate change will shift the frequency, intensity, duration and persistence of extreme hydro-climate events and may have particularly disastrous consequences in vulnerable systems such as the warm permafrost-dominated Interior region of Alaska. This presentation is divided into two parts. The first will document historical data analysis using recent research results from non-parametric trends and nonstationary generalized extreme value (GEV) analyses at eight Interior Alaskan river basins for 1950-2012. The second part of the talk will focus on the 2013 Alaskan spring breakup and June heat wave, highlighting the event within the context of long term historical data for Alaska.

Trends analysis of maximum and minimum streamflow indicates a strong (> +50%) and statistically significant increase in 12-day flow events during the late fall/winter and during the snowmelt period (late April/mid-May), followed by a significant decrease in the 12-day flow events during the post-snowmelt period (late May and into the summer). The March-April-May seasonal trends however, are towards significant decreases (> -50%) in maximum streamflow on snowmelt systems, while summer declines dominated for glacial-nival basins. This highlights the importance of analyzing trends across multiple time scales. Annual maximum streamflow trends indicate that most systems are experiencing declines, while minimum flow trends are largely increasing. Nonstationary GEV analysis identifies time-dependent changes in the distribution of winter and spring extremes, which may be indicative of shifting regimes linked to temperature increases or large-scale modes of climate variability. Springtime maximum flow increases are apparent on mixed glacial-nival basins (representative of increasing baseflow and time-shifting freshets), while declines in maximum streamflow occur in nival-dominated watersheds in relation to climate variability. An analysis using the precipitation and temperature regimes is also considered.

The breakup period of 2013 was one of the latest on record, with snowmelt occurring in late May leading to an extremely fast rate of melt. Due to the rapid nature of the melt, several ice jam events were triggered along the Yukon River. In the town of Galena, a massive ice jam flood devastated the town, destroying 90% of the buildings and forcing the population to relocate. However, the summer was one of the hottest on record for many locations in Alaska. A dry spell that lasted until November accompanied the hot weather. Records were broken at nine cities from June 17-19th. The heat wave was driven by large-scale circulation and not the land surface given that snowmelt was so late. The highest temperatures occurred when there was anomalous flow from the east, resulting in advection of warm continental air at the time of peak solar heating. Cooler maritime air that normally affects southern Alaska was effectively blocked off. Future model projections for maximum summertime temperatures indicate that these events will occur more frequently, particularly under the RCP 8.5 scenario.

Abstracts

2013 Extensive Yukon Ice Jam and Freshet Flooding

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Yukon Territory experienced widespread flooding, the most significant in several decades, during the spring of 2013. Seven flood events occurred at five communities during May and June, of which three were generated by ice jams and four were snowmelt driven. Both mechanisms were responsible for flooding at the same two communities within a period of two weeks. The winter was colder than normal resulting in a greater than normal river ice thickness. The snowpack to April 1 was variable throughout the Territory, with normal or below normal SWE amounts in southwestern and northern regions, and above normal in central and southeastern regions. The April 1st snowpack normally represents the maximum annual SWE; however, the spring of 2013 was anomalous. The monthly mean temperature for April was 3 – 7 °C below normal, with daily temperatures not rising above the freezing point until the beginning of May, two weeks later than normal. April is normally the driest month of the year, but April 2013 experienced amounts of widespread precipitation which was up to 250 percent of normal. The combination of the delayed melt and heavy April precipitation produced a May 1 snowpack with values of SWE which were 110 to 150+ percent of normal throughout central, southwestern and southeastern Yukon.

The return to normal temperatures occurred quickly in early May producing a rapid melt and runoff of the lower elevation snowpack. The likewise subsequent rapid increase in streamflow and water level resulted in a river ice break-up, while the ice cover was strong and competent, producing several ice jam events. The continued rapid melt of higher elevation snowpack subsequently produced snowmelt flooding at several locations.

Significant flooding also occurred during the spring of 2012 and in recent years previous, suggesting that the occurrence of flooding is increasing, possibly a result of increased winter precipitation and a compressed snowmelt and runoff period. There is some evidence to suggest that climate warming is responsible while teleconnections may also have an influence.

Abstracts

High Resolution Simulation of an Extreme Snow and Rain Event in Colorado in both a Current and Future Climate

Roy Rasmussen, Kyoko Ikeda and David Gochis
National Center for Atmospheric Research

Modeling of extreme weather events often require very finely resolved treatment of atmospheric circulation structures in order to produce and localize large magnitudes of moisture fluxes that result in extreme precipitation. This is particularly true for cool season orographic precipitation processes where the representation of landform can significantly influence vertical velocity profiles and cloud moisture entrainment rates. In this work we report on recent progress in high resolution regional climate modeling of the Colorado Headwaters region using an updated version of the Weather Research and Forecasting (WRF) model and a hydrological extension package called WRF-Hydro. Previous work has shown that the WRF-Hydro modeling system forced by high resolution WRF model output can produce credible depictions of winter orographic precipitation and resultant monthly and annual river flows. Here we present results from a detailed study of an extreme springtime snowfall event that occurred along the Colorado Front Range in March of 2003. Results from the impact of warming on total precipitation, snow-rain partitioning and surface hydrological fluxes (evapotranspiration and runoff) will be discussed in the context of how potential changes in temperature impact the amount of precipitation, the phase of precipitation (rain vs. snow) and the timing and amplitude of streamflow responses. It is shown that under the assumptions of the PGW method, intense precipitation rates increase during the event and, more importantly, that more precipitation falls as rain versus snow which significantly amplifies the runoff response from one where runoff is produced gradually to where runoff is more rapidly translated into streamflow values that approach significant flooding risks.

Abstracts

Tuesday Public Talk

The Colorado Great Front Range Flood of 2013 – Lessons for Alberta

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The deadly flood that occurred in the Colorado Front Range during the week of September 10th, 2013 is believed to be the worst in the state history. It claimed several lives and damaged numerous homes and roads. In this presentation, we will present what has been learned so far from observations and hydrological modeling. Key elements that will be discussed are: 1) How well was the storm precipitation and flooding diagnosed? 2) How well was the storm timing and precipitation amount, pattern and character forecast?, 3) How well was the flooding forecast, and 4) How can we do better in the future. Finally, some of the lessons learned will be applied to Alberta, especially to locations in the foothills of the Rocky Mountains.

